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An assessment of biomass resources availability in Shanghai: 2005 analysis

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Abstract

An assessment of biomass resources in Shanghai in 2005 has been conducted for the purpose of evaluating the potential quantities that can be used for energy. This analysis contains the estimation of biomass quantities potentially available in four categories: agricultural residues, forest and wood mill residues, municipal solid wastes and excrement resources. The estimated total physical quantities of biomass resources available for energy in Shanghai in 2005 are 8.18795 million tons, with the annual energy potential of 1.7149 million tons of coal equivalent (TCE). The majority of biomass energy in Shanghai is produced from municipal solid wastes, followed by excrement resources and agricultural residues. The energy production from municipal solid wastes and excrement resources can be put on the agenda in Shanghai.

Keywords: Biomass; Municipal solid wastes; Agricultural residues; Bioenergy

Contents

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1. Introduction

Biomass is a renewable, potentially sustainable and relatively environmentally benign source of energy. If grown and utilized on a sustainable basis, biomass is carbon dioxide neutral [1]. Thus, the substitution of fossil fuels for energy production with biomass will result in a net reduction in greenhouse gas emissions and the replacement of a non-renewable energy source.

The energy stored within biomass can be effectively utilized as a carbon-neutral energy, hence countries throughout the world are pursing the introduction of biomass energy system [2–8]. In China, the Renewable Energy Law became effective on January 1, 2006 to promote the introduction of such system.

The use of biomass resources was seriously investigated first during the oil crisis of the 1970s [9]. However, the oil prices dropped after the crisis, and biomass lost its competitiveness with the fossil fuel. As a result, only a small fraction of biomass resources is currently used in China. Yet, the problem of global warming requires severe reductions in the use of fossil fuel. China now must engage in quantitative discussion of biomass resources available for use. With this purpose in mind, we have attempted to evaluate the potential quantities of biomass resources in China. As a part, a systematic analysis of the potential quantities of biomass resources availability in Shanghai has been carried out in this paper.

2. Natural conditions of Shanghai

Shanghai, a municipality directly under the Central Government, is the biggest city in China. It is situated at 31°14′ north latitude and 121°29′ east longitude. Shanghai lies in the middle of China's mainland coastline and Yangtze River's entrance to the sea, covering an area of 6185 km^2, with 145 km^2 of the city districts and 6040 km^2 of the suburban area.

Shanghai has a sub-tropical climate—mild and humid with four distinct seasons. It has a mean annual temperature of 15 °C and a mean annual precipitation of 1100 mm.

Shanghai is thick with natural rivers and branch streams mostly in the Taihu drainage area. The main waterways are the Huangpu River and its branch Wusong River (or Suzhou Creek).

Chongming Island in Shanghai is the third largest island in China, which is an alluvial island formed with soil carried by the Yangtze River. Other islands under Shanghai administration are Changxin Island and Hengsha Island etc.

More information about natural conditions of Shanghai can be found in the literature [10].

3. Biomass resources availability

Biomass is the oldest known and a renewable source of energy. Biomass differs from other alternative energy sources in that the resource is varied, and it can be converted to

energy through many conversion processes [11]. For the purpose of this analysis, biomass resources are divided into four general categories: agricultural residues, forest and wood mill residues, municipal solid wastes and excrement resources. Following is a description of the potential availability of biomass resources in Shanghai in 2005.

3.1. Agricultural residues

The quantities of the agricultural residues depend on the output of farm crops, and therefore, on the sown areas of farm crops. Fig. 1 shows the sown areas of farm crops in Shanghai from 1996 to 2005 (data obtained from the literature [10]). Because of capital construction of roads, housing and industries, the sown areas in Shanghai decreased during this time, which can be observed from Fig. 1.

After harvest, a portion of the agricultural residues could potentially be collected for energy use. Rice, wheat, cotton, oil-bearing crop, watermelons and muskmelons currently dominate planted cropland in Shanghai. Therefore, the analysis of this paper for the agricultural residues is limited to rice straw, rice husk, wheat straw, soybean straw, cotton stalk, oil-bearing crop stalk, bine and leaf of watermelon and muskmelon.

The quantities of the agricultural residues that can be available in Shanghai are estimated by first calculating the total quantities of residues produced and then calculating the total quantities that can be collected after taking into consideration the quantities that must be left to maintain soil quality (i.e., maintain organic matter and prevent erosion [12]).

The generated quantities of the agricultural residues are estimated using the output of crops and the residue factors (the residue factor is named sometimes in the literature as the ratio of grass to grain [13]). The production data for farm crops in Shanghai in 2005 are shown in Table 1. The results included in Table 1 show that the total quantities of the agricultural residues in Shanghai in 2005 are 1.52525 million tons, with the energy potential of 684.79 thousand tons of coal equivalence (TCE).

The net quantities of the agricultural residues that are available for collection are estimated by subtracting from the total agricultural residue quantity generated, the

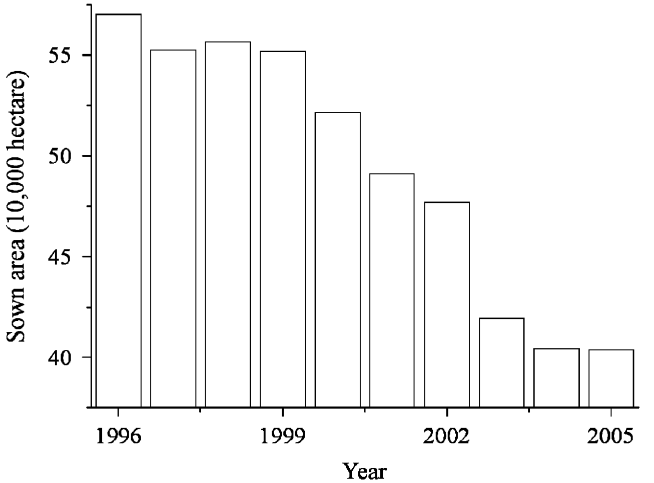

Fig. 1. The sown areas of farm crops in Shanghai from 1996 to 2005.

quantities of residues that must remain to maintain soil quality. Quantities that must remain differ by crop type, soil type, typical weather conditions, and the tillage system used. An average has been used for this analysis. In general, about 60% of the residues can be collected [5].

Therefore, the estimated physical quantities of the agricultural residues' availability in Shanghai in 2005 are 915.15 thousand tons, with the energy potential of 410.874 thousand TCE.

3.2. Forest and wood mill residues

The forest residues can be grouped into the following categories—logging residues; rough, rotten, and salvable dead wood; excess saplings; and small pole trees [14]. Logging residues are the unused portions of the growing of stock trees that are cut or killed by logging and left behind. Rough trees are those that do not contain a sawlog or are not a currently merchantable species. Rotten trees are trees that do not contain a sawlog because of rot. Salvable dead wood includes downed or standing trees that are considered currently or potentially merchantable. Excess saplings are live trees having a diameter breast height greater than 5 in, but smaller than saw timer trees. For the purpose of this analysis, we have included only logging residues and rough, rotten, and salvable dead wood quantities. Polewood, which represents the growing stock of merchantable trees, has not been included in the analysis due to the fact that it could potentially be left to grow and use for higher value fiber products. It is doubtful that these trees will be harvested for energy use.

Wood mill residues generated at wood mills (i.e., mills producing lumber, pulp, veneers, other composite wood fiber materials) are classified by type and include bark; coarse residues (chunks and slabs); and fine residues (shavings and sawdust).

Over the past 6 years, the percentage of Shanghai's land area covered by forests has risen from 3.17% in 1999 to 11.04% in 2005 [10]. Shanghai's forest area in 2005 amounts to 59.7 thousand hectares, and the total standing stock volume is 2752 thousand cubic meters, and the stock volume of the forest is 1009.5 thousand cubic meters. Timber cutting volume of Shanghai in 2005 amounts to 6.9 thousand cubic meters.

Table 1
The output of the major farm crops and the total quantities of the agricultural residues in Shanghai in 2005[a]

Crop	Output (10,000 ton)	Residue factor	Agricultural residues (10,000 ton)	Coefficient of conversion	Standard coal (10,000 TCE)
Rice[b]	85.45	1.2	102.54	0.429	43.990
Wheat	12.78	1.0	12.78	0.5	6.390
Soybean	7.13	1.5	10.695	0.486	5.198
Cotton	0.18	3.0	0.54	0.571	0.308
Oil-bearing crop	6.51	2.0	13.02	0.441	5.742
Watermelons and muskmelons	64.75	0.2	12.95	0.529	6.851
Total	176.8		152.525		68.479

[a]Data obtained from the literature [10].

[b]Rice residues include rice straw and rice husk. The residue factor of rice straw is 1.0, and rice husk makes up 20% of rice by mass [1].

The forest and wood mill residue supplies that could potentially be available for energy use in Shanghai are estimated using a model presented by Gu et al. [13]. Thus, the estimated total forest and wood mill residue quantities' availability in Shanghai in 2005 are 3.2 thousand tons, equaling 3.3 thousand TCE.

3.3. Municipal solid wastes

Generated by household and commercial activities, most municipal solid wastes are currently disposed of in landfill sites. However, the disposal of this waste is a growing problem worldwide. Much of the waste can be used for energy production through incineration and other processes. It is also possible to use the methane produced in landfill sites for energy production. Municipal solid waste is made up of different organic and inorganic fractions like food, vegetables, paper, wood, plastics, glass, metal, and other inert materials [15]. The contents of the typical municipal solid wastes in Shanghai are shown in Table 2 [16]. The average heating value of municipal solid wastes in Shanghai is about 4200 kJ/kg, and the coefficient of conversion to standard coal is about 0.12 [16].

As a result of rapid population growth and the increased rate of unplanned urbanization in Shanghai, the amount of municipal solid wastes is increasing. Fig. 2 shows the amount of municipal solid wastes in Shanghai from 1978 to 2005 (data obtained from the literature [10]). In 2005, the total amount of municipal solid wastes in Shanghai is up to 6.22 million tons.

Using the total amount of municipal solid wastes and the coefficient of conversion to standard coal, the potential energy content of municipal solid wastes' availability in Shanghai in 2005 is estimated and equals 746.4 thousand TCE.

3.4. Excrement resources

As the important raw materials, excrement resources can be used for the production of biogas, an economical source of energy [17]. Most animal excrement resources in Shanghai are produced from pigs, cows, sheep, rabbits, and poultry birds.

The potential quantities of animal excrement resources are estimated using number of animals, annual excrement production of one animal, coefficient of excrement collection, dry excrement fraction, and coefficient of conversion to standard coal. The potential quantities of human excrement resources are estimated using annual amount of human excrement disposal cleared, dry excrement fraction, and coefficient of conversion to standard coal. Table 3 presents excrement resources available for energy in Shanghai in 2005. The energy content of excrement resources is also included in Table 3.

The total physical quantities of dry excrement resources are 1.0496 million tons, with the energy potential of 554.3 thousand TCE.

Table 2
Percentages of the contents of the typical municipal solid wastes in Shanghai

Food	Paper	Plastics	Wood	Ash	Glass	Metal	Other
71.6	8.6	8.8	3.9	1.8	4.5	0.6	0.2

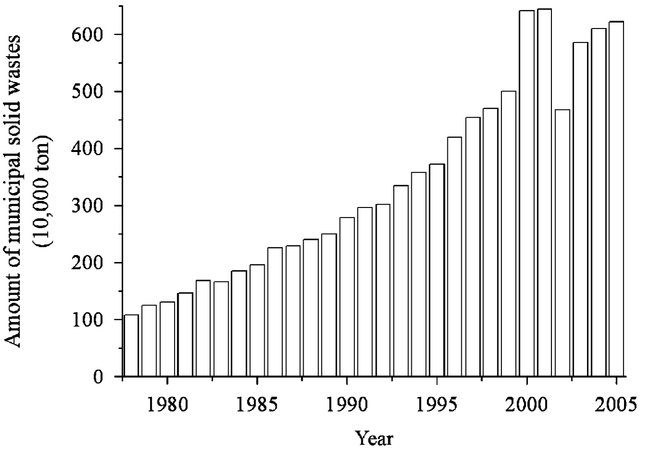

Fig. 2. The amount of municipal solid wastes in Shanghai from 1978 to 2005.

Table 3
Excrement resources in Shanghai in 2005[a]

	Pigs	Cows	Sheep	Rabbits	Poultry birds	Human	Total
Number of animals (10,000 head)	433.16	5.33	30.08	31.5	7461	–	–
Annual excrement production of one animal (ton/head)	0.6	7.3	0.1825	0.018	0.006	–	–
Coefficient of excrement collection	1	0.6	0.6	1	0.6	–	–
Amount of collected excrement (10,000 ton)	259.90	23.35	3.29	0.57	26.86	254[b]	567.97
Dry excrement fraction (%)	20	18	40	100	80	10	–
Amount of dry excrement (10,000 ton)	51.98	4.20	1.32	0.57	21.49	25.40	104.96
Coefficient of conversion to standard coal	0.429	0.471	0.529	0.529	0.643	0.643	–
Standard coal (10,000 TCE)	22.30	1.98	0.70	0.30	13.82	16.33	55.43

[a]Data obtained from the literature [10].
[b]Amount of human excrement disposal cleared.

4. Summary

Interest in using biomass resources to produce energy in China is increasing. Central to determining the potential quantities of biomass resources in China is an understanding of their location and quantities. As a part, this paper describes biomass resources availability in Shanghai in 2005. Table 4 summarizes the estimated total quantities of biomass resources available for energy in Shanghai in 2005. From Table 4, it can be obtained that the total energy content of biomass resources' availability in Shanghai in 2005 is up to 1.7149 million TCE. The majority of biomass energy in Shanghai is produced from

Table 4
The estimated total quantities of biomass resources availability in Shanghai in 2005

	Agricultural residues	Forest and wood mill residues	Municipal solid wastes	Excrement resources	Total
Physical quantity (10,000 ton)	91.515	0.32	622	104.96	818.795
Standard coal (10,000 TCE)	41.09	0.33	74.64	55.43	171.49

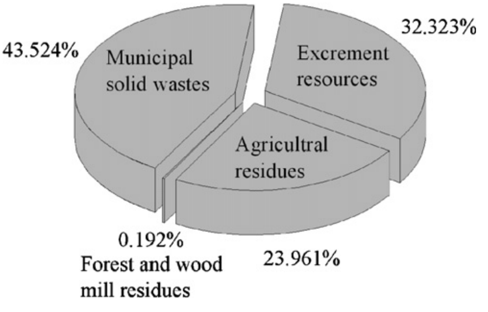

Fig. 3. The pie chart of biomass resources availability in Shanghai in 2005.

municipal solid wastes (43.524%), followed by excrement resources (32.323%) and agricultural residues (23.961%), which can be seen from Fig. 3. Therefore, the energy production from municipal solid wastes and excrement resources can be put on the agenda in Shanghai. However, further studies are required to estimate the collection and conversion cost of biomass resources.

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